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The John A. Blume Earthquake Engineering Center

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SPECIAL WELCOME

As the summer draws to a close and the new '95-'96 academic year begins, the Blume Center wishes to welcome back all the returning Stanford students as well as the new members of the Structural Engineering Graduate Program. In addition, we'd like to both introduce and welcome the following visiting scholars and researchers.

Professor Gregory G. (Greg) Deierlein holds the 1995-1996 UPS Foundation Visiting Professorship at Stanford while on sabbatical leave from Cornell University. Professor Deierlein's research interests are in the design and behavior of steel and composite steel-concrete structures with an emphasis on seismic design. He is active in several professional organizations including the AISC subcommittee on Seismic Design and the ASCE committee on Composite Structures. He currently chairs the BSSC/NEHRP task committee on composite steel-concrete construction and the SSRC task group on frame stability. While at Stanford, Professor Deierlein will be teaching CE 283 - Nonlinear Structural Analysis during Winter Quarter.

Sayaka Irie, a staff science writer for the Yomiuri Shimbun Newspaper, is on leave this year to study earthquake engineering at Stanford. Ms. Ifie has been with the the Yomiuri Shimbun Newspaper, the largest daily newspaper in Japan, for eight years and will use her time at the Blume Center to pursue her interests in GIS and hazard reduction measures in the U.S.

Tomohiko (Tom) Hatada, on leave from Kobori Research Complex of Kajima Corporation in Japan, is joining the Engineer's Degree Structural Engineering Program for two years starting this autumn. He received his B.S. and M.S. from Kobe University, and has worked as a Research Engineer at Kajima under the guidance of Dr. Takuji Kobori. Tom will be studying nonlinear active structural response control and its application to structural design under the advisement of **Professor H. Allison Smith.**

Returning to the Blume Center is **Hjortur Thrainsson,** who received two prior Structural Engineering degrees from Stanford [M.S., 1989; Eng. Deg., 1991]. Hjortur has been working as a Research Engineer at the Applied Mechanics Laboratory of the Engineering Research Institute at the University of Iceland, his undergraduate alma mater. He will be studying hazard and risk analysis and damage evaluation under the guidance of **Professor Anne Kiremidjian.**

CENTER NEWS

Professor Helmut Krawinkler spent the Spring Quarter as a Visiting Professor at his alma mater, the Technical University of Vienna in Austria. He devoted his time to writing, developing new research ideas and giving seminars with colleagues at universities in Austria, Germany, Hungary, Norway, and Italy.

Professor Anne Kiremidjian was invited to give one of the four presentations at the CUREe Open Symposium: *Lessons Learned from Northridge to Kobe,* held June 14 at Kajima in Tokyo. She spoke on "Methodologies for Evaluation of the Socio-Economic Consequences of Large Earthquakes."

On May 26, the Blume Center faculty met with the Impact Problems Subcommittee of the Japan Society for Civil Engineers to discuss the effect of near-field vertical earthquake ground motion on brittle structures.

In June, **Dr. Stephanie King** presented a paper entitled, "Observations from the 1995 Kobe Earthquake and Implications for Urban Earthquake Disaster Reduction," at the UNESCO International Workshop on Earthquake Disaster Reduction in Urban Areas, Jakarta, Indonesia.

In August, **Professor Anne Kiremidjian** co-chaired the 4th US Conference on Lifeline Earthquake Engineering, which was sponsored by ASCE and held in San Francisco.

On August 11, **Professors H. Allison Smith** and **Kincho Law** and **Dr. Weimin Dong** of the Blume Center hosted a visiting delegation from the Ministry of Construction in Beijing, China.

Professors Martin Fischer, Kincho Law, and **Bart Luitten** organized an international workshop on "Modeling of Buildings through their Life-cycle" held at Stanford August 21-23. The workshop was sponsored by the Working Commission of "Information Technology in Construction" and the Task Group on "Computer Representation of Design Standards and Building Codes" of the International Council for Building Research Studies and Documentation.

In July, **Professor Peter Pinsky** gave a series of invited lectures at the University of Stuttgart, Germany, on the topic of new finite element methods for wave propagation in fluid-loaded structures.

Professor Ronaldo Borja presented a paper at the 5th International Symposium on Numerical Models in Geomechanics in Davos, Switzerland, September 6-8.

RESEARCH SPOTLIGHT

Large Scale Engineering Computations on Distributed Memory Parallel Computers and Distributed Workstations

Project Sponsor: National Science Foundation

Project Coordinator: Professor Kincho H. Law, Stanford University

Research Assistants: Dr. David Mackay (former Ph.D. student); Dr. Made Suarjana (former Ph.D. student); Eduardo De Santiago

Significant advances in hardware and software technologies have been made in parallel and distributed computing during the last decade., Distributed memory machines have evolved to be the standard architecture for commercial parallel computers. On the other hand, networked workstations have become an inexpensive and attractive alternative for scientific computing. The development of an efficient parallel or distributed application software is far more difficult than that of serial programs. This brief note summarizes the computational models that we have employed for parallel and distributed **finite** element computing.

Parallel Computational Model

A distributed memory computer consists of a number of processors; each processor has its own CPU and local memory units. The processors synchronize and share data via messages sent through a dedicated interconnecting network. For such a computer architecture, the most commonly employed program model for implementing parallel programs for engineering applications is the single-program-multiple-data (SPMD) paradigm. In this approach, a given problem is decomposed using a domain decomposition technique to partition a domain into a number of subdomains. Each processor of the parallel machine serves a partitioned domain. Data communication between domain partitions is performed among processors through message passing.

A typical finite element code contains the following modules: a pre-processor, element generation, matrix formation and a linear equation solver and an eigenvalue solver. For nonlinear problems, an iterative nonlinear solution strategy is employed. Generally, the pre-processing routines supporting problem definition, grid generation, 110, and other file management functions take negligible time and are inherently serial. Element generation can be performed concurrently on different processors. Parallel communications among processors are limited primarily to the equation and eigenvalue solvers. For large scale engineering software, beside optimizing the parallel kernels for linear algebraic and/or matrix computations, attention must be paid to the overall program structure and the data flow among the program modules. Special care is needed in setting up the data structure required by each processor and in ensuring proper data flow between the pre-processor and the parallel FEM program.

Numeric algorithms that are efficient on a sequential work- station or mainframe may not be efficient on a parallel computer. For example, in the parallel implementation of a employed a sparse solution technique which first into diagonal and off-diagonal blocks and then "partially" inverts the principal (triangular) submatrices [1]. Although matrix inversion requires more computations, the matrix inverses greatly facilitate the forward and backward triangular solutions by replacing the triangular solution (which is a highly data dependent process) with a matrix-vector multiplication (which has less data.dependency and thus can be computed synchronously on different processors with minimum communications). Figure I shows the illustrative result in solving a generalized eigenvalue problem of a 220 by 220 square grid model (with 97,674 equations) using 40 Lanczos iteration steps on an Intel Paragon Parallel Computer. This illustrative result clearly demonstrates the benefit of partially inverting the matrix factor and reveals the difference in the implementation of a numerical algorithm on a sequential workstation and a parallel computer. Detailed 0
studies of parallel finite element structural engineering programs for static, dynamic, nonlinear problems using direct and iterative solution techniques can be found in the Ph.D. theses by David Mackay [I) and Made Suarjana [2].

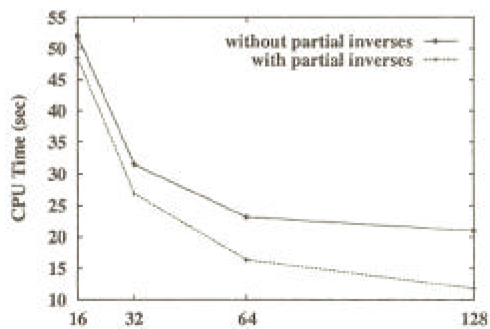


Figure 1: CPU Time for a Generalized Eigenvalue Problem on Intel's Paragon Parallel Computer

Distributed Computational Model

With the rapidly decreasing cost of workstations and the advances in networking hardware and software technologies, an attractive and inexpensive alternative way to achieve modest scale performance is to develop engineering application software that can run on a network of distributed workstations. At first glance, the same SPMD model for parallel computing appears to be a natural and intuitive approach for the implementation of a distributive engineering application. In practice, however, a distributive engineering application software must take into consideration at least three basic issues:

RESEARCH SPOTLIGHT

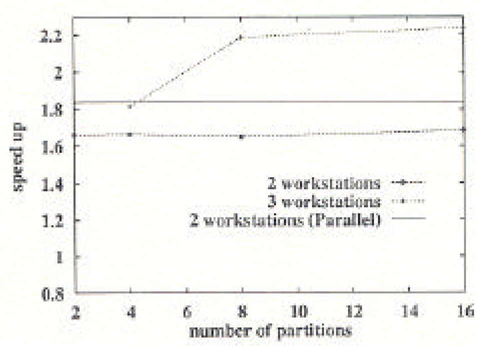
1. Unlike parallel computers where each processor has the same CPU and memory units, workstations in a network are likely to have different hardware units, to be heterogeneous.
2. Workstations are employed to support multiple users and to run multiple jobs simultaneously.
3. In a distributed environment the likelihood of one of the workstations becoming heavily loaded or inoperative during the execution of the application software must be taken into account.

The SPMD model that assumes equal work load on each processor is not necessarily an optimal or a practical paradigm in a heterogeneous, multi-user network environment. In an industrial setting where each of the workstations on the network resides in a different office, or perhaps in an entirely different building, and is tinder direct control of distinct individuals, each with their own agenda, it is quite possible that a task could be killed off at a remote site by the owner of the machine if he or she thinks that the task is slowing down the machine too much. For these and other reasons, a distributed program must include a fault recovery scheme to ensure robustness.

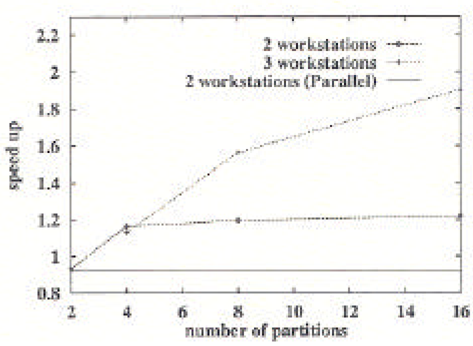
We employ a "pool of task" and "master-slave" paradigm for implementing the distributed program. The strategy is to decompose an application into a number of tasks for distribution among the workstations. Initially, a finite element problem is partitioned into a number subdomains (more than the number of workstations to be used). The master task in the host workstation is mostly used for pre-processing, collecting the output, and distributing the partitions of the domain among the slaves. For each nonlinear (time) steps, each slave workstation is first assigned a single subdomain to be processed. Once the slave workstation completes the matrix formation for the subdomain assigned, it then requests another subdomain from the host workstation, and so forth. In our work, a fault is assumed to have occurred in the system if a receive operation does not complete before a specified length of time expires. The task where the time-out occurs is responsible for advising the other tasks in the configuration that a fault has occurred. All points of communication will act as checkpoints for determining whether the fault has occurred. Once a fault has been detected, the master task is responsible for determining which workstations have failed and for re-distributing the failed partitions (i.e. partitions that have been previously assigned to the failed workstations) to the remaining slave workstations.

The application domain involves the solution of the incompressible Navier-Stokes equations using a Galerkin/Least Squares finite element formulation. Figure 2 shows the preliminary result that we have obtained for a 2D example on fluid flow passing a circular cylinder. Speed-up is measured relative to the elapsed time of the sequential program running on a workstation. Detailed description of the distributed program is presented in "An Implementation of Finite Element Method on Distributed Workstations" [3].

Summary
In this note, we have briefly discussed the programming models required to take advantage of the parallel and distributive computer architectures. Our results demonstrate that significant performance can be achieved on parallel as well as distributed computers with appropriate computational models.



(a) Example of Run on Distributed Workstations



(b) Example Run on Distributed Workstations (with one work-station loaded)

Figure 2: Speed-up for a Flow through a Cylinder Example on SUN's Workstations

References

[1] D.R.Mackay, Solution Methods for Static and Dynamic Structural Analysis on Distributed Memory Computers, Ph.D. Thesis, Department of Civil Engineering, Stanford University, 1992.
[2] M. Suarjana, Conjugate Gradient Method for Linear and Nonlinear Structural Analysis on Sequential and Parallel Computers, Ph.D. Thesis, Department of Civil Engineering, Stanford University, 1994.
[3] E. De Santiago and K.H. Law, "An Implementation of Finite Element Method on Distributed Workstations," to be presented at the ASCE Structures Congress XIV, Chicago, 11, April, 1996.

NEWLY PUBLISHED TECHNICAL REPORTS

No. 116 - *H-infinity Control for Vibration Control of Civil Structures in Seismic Zones* by J. Geoffrey Chase and Professor H. Allison Smith, September, 1995.

NEWLY SPONSORED RESEARCH PROJECTS

Adaptive Control of Smart Structures with Time Variant Stiffness and Damping: The Effects of Actuator Nonlinearity on Acoustical Boundary Control, sponsored by the Naval Research Laboratory. Principal Investigator: Professor H. Allison Smith. 411/95 - 3/31/96

Information Management for Regulations and Codes, sponsored by CIFE. Principal Investigators: Professors Michael Genesereth, Kincho Law, Gio Wiederhold, and Dr. John Kunz. 10/l/95 - 9/30/96

Interpreting Process and Instrumentation Diagrams, sponsored by CIFE. Principal Investigators: Professors Thomas Binford and Kincho Law and Dr. John Kunz. 10/l/95 - 9/30/96

ALUMNI NEWS

Stephanie King [Ph.D.,'94], part-time post doctoral fellow with Professor Anne Kiremidjian, is a project manager with GeoHazards International, which is affiliated with Stanford's Departments of Civil Engineering and Geophysics.

Kimberly Lutz [Ph.D.,'93] and her husband, Steve Lutz, welcomed the birth of their second child, Meredith, in May. Kim is a Senior Engineer with Jack R. Benjamin & Associates in Mountain View.

Mohsen **Rahnama** [Ph.D. '93] returned to the Bay Area after a two-year stay in Iran as a faculty member at Sharif Technology University in Tehran. He is now working with Krawinkler, Luth, and Associates in Menlo Park.

Doug Schmucker [M.S. '91; Ph.D.'95] has joined the faculty of the Department of Civil Engineering at Pennsylvania State University.

Edward Thonietz [M.S., 1991) has returned to the U.S. after spending three years at Obayashi Corporation in Japan. Ed and his wife, Asami, will be living in Southern California.

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